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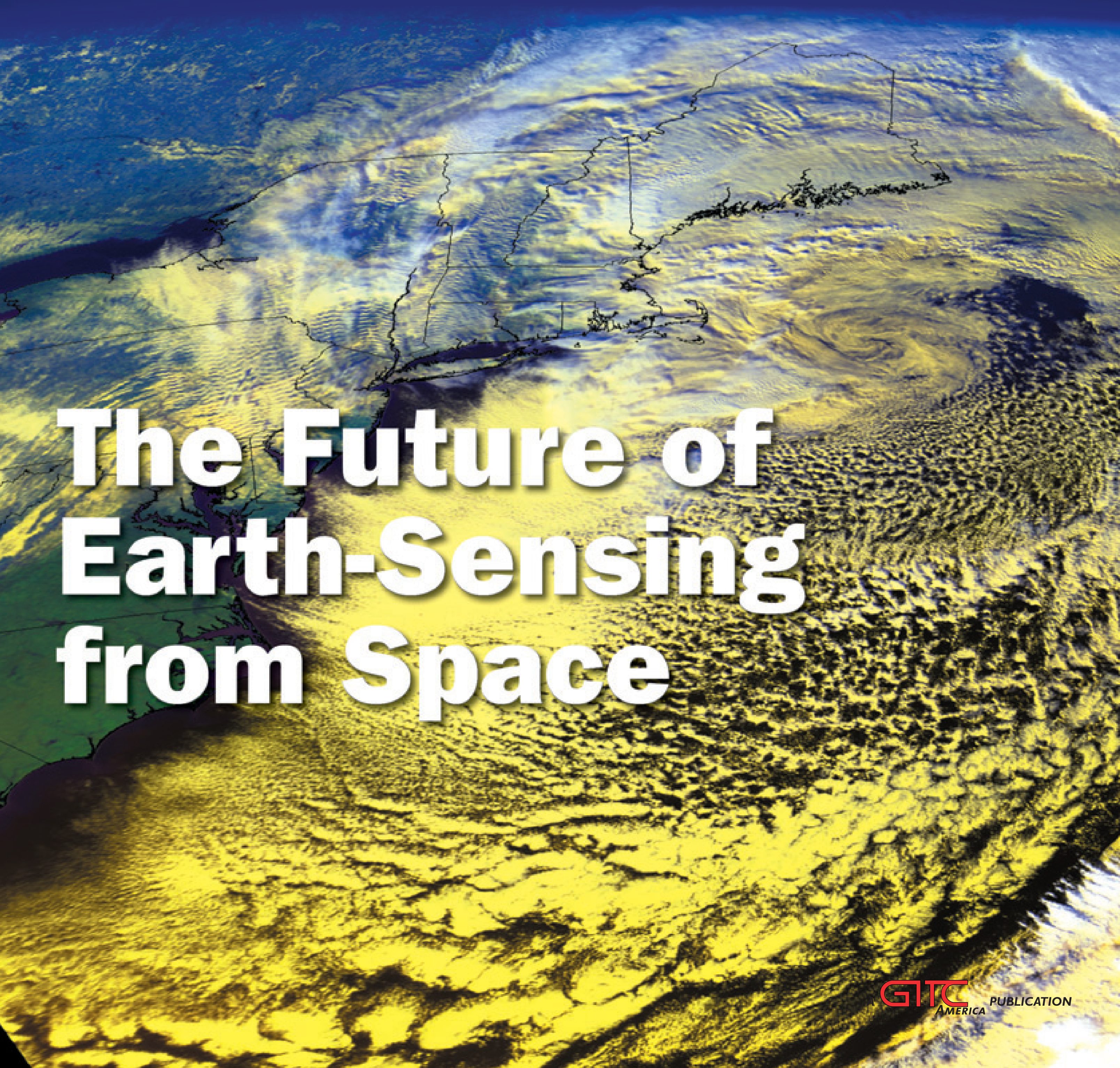


The Future of Earth-Sensing from Space

GITC America PUBLICATION

The Future of Earth-Sensing from Space

This article is the first of a 12-part series on the next-generation of Polar-orbiting Operational Environmental Satellites (POES) and the benefits they provide now, and will provide in the future, to a broad and diverse community of users. From defense and civilian applications to weather forecasting for the public, the satellites of the future have a critical role to play in increasing our understanding of the earth as a system while providing for our safety on a daily basis.

Dave Jones

The articles presented over the next twelve months will focus specifically on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program and its mission to create a single cost-effective, high performance, integrated satellite system operated by the federal government. Each month we will look at topics related to the development, technology, and applications of NPOESS.

Polar-orbiting and Geostationary: The Difference

Orbiting at an altitude of approximately 833 km (520 miles) above the earth and traveling at speeds of up to 17,000 miles per hour, Polar-orbiting Operational Environmental Satellites (POES) continuously observe the Earth. Our "eyes in the sky," POES orbit our rotating planet approximately 14 times each day and are able to scan almost the entire surface of the Earth twice daily. A constellation of three satellites can cover the entire globe every four hours. They provide exceptional coverage of the entire Earth on a regular basis. Instruments mounted on the satellites continually collect and distribute a wealth of data to users such as scientists, researchers, weather forecasters, military personnel, emergency management officials, space weather scientists, and rescue workers. Dr. Max Mayfield, Director of NOAA's National Hurricane Center says, "The Polar-orbiting Satellites have started to provide extremely valuable data to tropical forecasters… the SSM/I sensor on the DMSP satellite and TRMM and Quickscat data from NASA are all now used operationally at the National Hurricane Center." Storage of the data allows for time series comparisons for the monitoring of environmental change, natural hazards and their impacts, and a look into the dynamics of the atmosphere, land, and ocean systems that affect our life on Earth.

A second type of operational environmental monitoring satellite called a Geostationary Operational Environmental Satellite (GOES) also collects observations from space. As compared to

Polar-orbiting satellites circle the earth at 850 km while Geostationary satellites orbit much further out in space at 35,800 km.

THE NEXT GENERATION SATELLITE SERIES: A LOOK AT NPOESS AND ITS BENEFITS

Polar-orbiting satellites, GOES are in more distant orbits, positioned some 36,000 km (~22,300 miles) from the earth. These satellites fly in an orbit above the equator at the same rate as the earth turns; consequently they always remain over the same point on the Earth. GOES satellites provide continuous coverage of the western hemisphere at middle and lower latitudes.

Data from instruments aboard GOES provide information to a variety of users, but are particularly important for monitoring the weather on a daily basis in near real-time. Most people are familiar with GOES images because they are frequently used by weathercasters on television in North and South America and weather-related websites.

Operating the Nation's Environmental Satellites

Polar-orbiting Satellites

Currently, the Department of Defense (DoD) has two primary Polar-orbiting "weather" satellites that are operated by the National Oceanic and Atmospheric Administration (NOAA). These satellites and their instrument payloads are used to fulfill the mission of DoD's Defense Meteorological Satellite Program (DMSP), which focuses on supplying weather and other environmental information to support military operations.

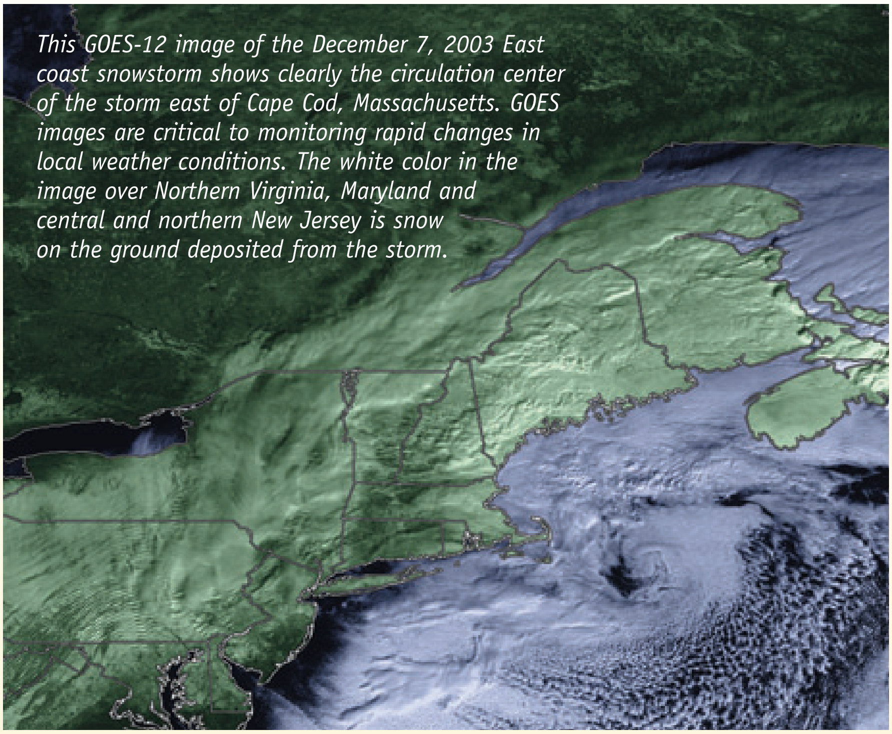
The National Aeronautics and Space Administration (NASA) (See sidebar on page 8) currently has 18 research and development Polar-orbiting satellites on orbit. Sensors for the satellites are developed, tested, calibrated, and validated with *in situ* data. NASA also uses the data from its research satellites to study the Earth as a system and to determine how it is changing. Global climate change research is a particular priority. NASA's Earth Observing System (EOS) program has provided invaluable information of national importance in areas such as agricultural efficiencies, air quality, carbon management, homeland security, disaster management, and public health.

Currently, onboard NASA's 18 Polar-orbiting satellites there are approximately 80 sensors that collect nearly three terabytes worth of information every day. NASA's EOS program is also providing a proving ground for next-generation sensor and satellite technology.

Polar-orbiting environmental satellites and sensors may be transitioned from research and development at NASA to operations at NOAA. Technologies developed and tested by NASA on research spacecraft, when proven useful for operations, may result in a suitable version being designed for use by NOAA. Sensors that do fly on an operational platform become the responsibility of NOAA. Over the past 40 years, NASA has been the acquisition agent for all of NOAA's operational satellites.

After successful launch, testing, calibration, and validation by NASA, NOAA assumes all operational responsibility for the environmental observation satellites. NOAA currently operates two primary POES spacecraft (NOAA 16 and 17) and the two DMSP weather satellites.

Operational uses of POES data include global measurements that are critical to determining the initial state of



This GOES-12 image of the December 7, 2003 East coast snowstorm shows clearly the circulation center of the storm east of Cape Cod, Massachusetts. GOES images are critical to monitoring rapid changes in local weather conditions. The white color in the image over Northern Virginia, Maryland and central and northern New Jersey is snow on the ground deposited from the storm.

the atmosphere for input into numerical weather prediction models. This input is critical to maximize the accuracy of model forecasts both locally and globally. The forecasts produced by these models are the foundation of products used to inform and protect the U.S. public. High-resolution imagery is also used for fire mapping, agricultural applications, and natural and man-made hazard monitoring. POES also provides critical monitoring of our near space environment. Violent solar storms and flares can interrupt critical systems on earth. The POES platforms keep monitoring incoming particles that could disrupt power generation grids, communication lines, and other satellites orbiting the earth.

Geostationary Satellites

NOAA operates the nation's GOES system through the National Environmental Satellite, Data, and Information Service (NESDIS), the same organization that operates POES and DMSP. As part of the system, GOES West, observes the Earth from Hawaii to the mid-U.S., and GOES East from the mid-U.S. to Africa. NOAA's operational uses of GOES data include weather analysis and forecasting, fire mapping, climate science, and more.

The main federal user of U.S.-based GOES platforms currently orbiting the planet is NOAA's National Weather Service (NWS), though other government agencies also benefit from the data these satellites provide. The NWS is responsible for providing official weather forecasts, as well as issuing watches and warnings of hazardous weather events, such as hurricanes.

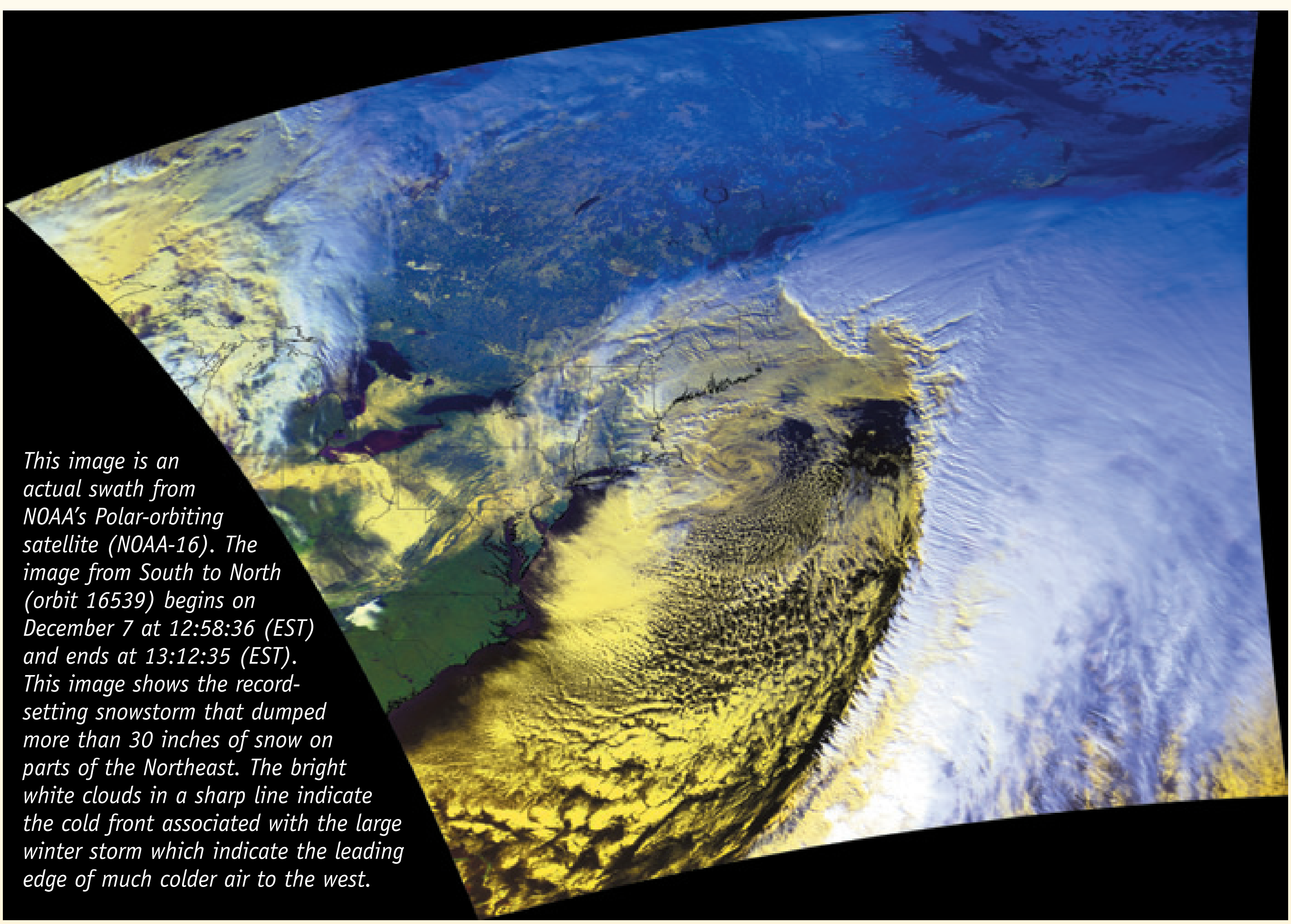
GOES platforms also provide the private sector with timely images of cloud cover, which are updated every 15 to 30 minutes. These images are enhanced for use by private weather services and transmitted to the broadcast media and other customers for integration into customized information products.

Together, the operational constellations of POES, DMSP, and GOES deployed by the U.S. provide a complete space-based global weather monitoring system that is critical to fulfilling the missions of NOAA and the DoD. Both agencies, in large part, are tasked to protect life and property, and provide environmental information that can be used to help enhance the national economy and to provide real-time support to military operations.

In general, GOES provides critical imagery of weather systems in a timely and reliable fashion while POES provides critical input to numerical weather prediction models by gathering global data on a regular and consistent basis.

NPOESS

The future of both NOAA and DoD's Polar-orbiting program is the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The NPOESS program was developed to employ next-generation platforms and instruments in an integrated mission



This image is an actual swath from NOAA's Polar-orbiting satellite (NOAA-16). The image from South to North (orbit 16539) begins on December 7 at 12:58:36 (EST) and ends at 13:12:35 (EST). This image shows the record-setting snowstorm that dumped more than 30 inches of snow on parts of the Northeast. The bright white clouds in a sharp line indicate the cold front associated with the large winter storm which indicate the leading edge of much colder air to the west.

serving the nation's needs for space-based, remotely sensed environmental data. With NOAA, the DoD, and NASA all playing integral roles, NPOESS promises greater coordination, more cost effectiveness, and a wider applicability for the nation's satellite programs.

The past success in transitioning Polar-orbiting Environmental Satellites from a research to an operational mode is the foundation upon which the U.S. will build an optimal NPOESS program. NASA is contributing its technology and sensor expertise, while DoD and NOAA are sharing the cost of building and operating the NPOESS system. The prime contractor for the program is Northrop Grumman Space Technology, while Raytheon is the largest subcontractor. The Department of Commerce, Department of Defense, and NASA jointly created the NPOESS Integrated Program Office (IPO) in 1995 to develop, acquire, manage, and operate the NPOESS system.

NASA began researching and testing the next-generation sensor technologies that will fly on NPOESS satellites during its EOS missions. The new instruments will be used to monitor global environmental conditions and collect and disseminate data related to the weather and atmosphere, as well as ocean, land, and near-space environments for NOAA and DoD. As both agencies currently operate separate satellite platforms, consolidating their efforts into NPOESS is expected to cut costs and provide access to leading-edge technology for both.

The Department of Defense will use data collected by NPOESS satellites to support defense-related applications. NOAA will use the satellites to collect additional data for use as input to sophisticated numerical weather prediction models and to better understand how the earth's climate is changing over time. Additionally, scientists and the public will be provided data and information from the federal agencies that will be of practical value in areas such as agriculture, marine operations, weather, storm warnings, and emergency response. NASA will support the research portion of NPOESS and continue to pursue technology development with separate research missions, vehicles, and flights for possible transition to operations in the future.

The Satellite Era Begins

A little more than 50 years ago, in 1952, the International Council of Scientific Unions (ICSU) took a step toward the satellite age. In recognition of a high point in solar activity between July 1, 1957 and December 31, 1958, the ISCU declared that period as the International Geophysical Year (IGY).

As part of the IGY, in October, 1954, the ICSU adopted a resolution calling for satellites to be launched for the purpose of mapping the surface of the Earth. One year later, the U.S. announced plans to launch an Earth-orbiting satellite. In 1955, the U.S. selected the Naval Research Laboratory (NRL) to build and launch the first satellite.

However, the U.S. was in for a shock as on October 4, 1957 the Soviet Union successfully launched Sputnik I, the world's first satellite. About the size of a basketball, weighing 183 pounds, and traveling in an elliptical orbit about the Earth, Sputnik made a complete trip around the planet in 98 minutes.

For the Soviets, Sputnik was an impressive technical achievement that caught the world's attention, but for the U.S. it was a stunning blow to fall behind in the race for space. Sputnik's size was greater and more impressive than NRL's intended 3.5-pound satellite payload. But, more importantly, the public quickly began to fear that if the Soviets had the technology to launch satellites, they might also be able to use it to launch nuclear missiles at the U.S. from the Soviet Union or Europe.

Immediately after the Sputnik I launch, the U.S. Department of Defense responded to growing political furor over the Soviet "first" in space, by approving funding for another U.S. satellite project. As plans for NRL's Vanguard satellite continued, Werner Von Braun and his Army Redstone Arsenal team began work on the Explorer satellite project.

In the meantime, the Soviets launched Sputnik II on November 3, 1957. Sputnik II carried a different and innovative payload—a dog named Laika.

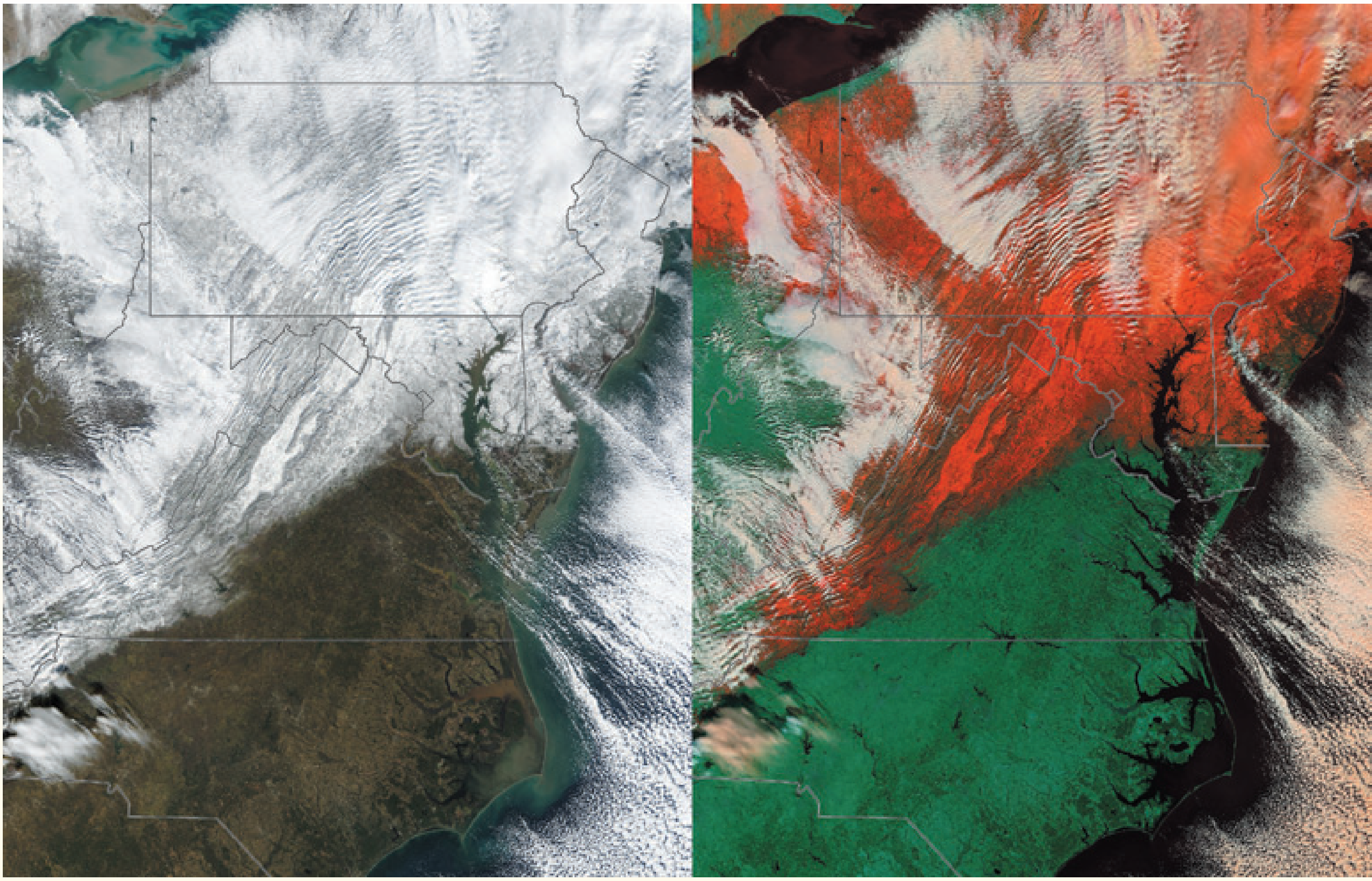
On January 31, 1958, the U.S. successfully launched Explorer I. The satellite carried scientific instrumentation that eventually led to the discovery of the Earth's magnetic radiation belts, which were named after their principal investigator, James Van Allen. The Explorer program continued with Explorer IV launched successfully on July 26, 1958. Explorer (Explorer V & VI) launches failed. After this time all of the launch agencies (Army, Air Force and NASA) learned around that time to cease assigning a number to a satellite until it was successfully in orbit. It also took awhile to discontinue Roman numeral use. The same Huntsville group that had worked on Army-launched Explorers continued with many NASA Explorers, but not all. Altogether about 59 satellites with the name "Explorer" were launched successfully from 1958 to 1981. Some of these also had other names, *e.g.* "GEOS; Geodetic Satellite" which was Explorer 29. A list of Explorer's is available on the web at *http://www.hq.nasa.gov/office/pao/History/explorer.html*.

In addition to launching the satellite age, Sputnik's orbit marked the beginning of the space race that consumed the minds and imaginations of people in the U.S. and the Soviet Union for the following decade.

Determined to be first in space in the future, in July 1958, Congress passed the National Aeronautics and Space Act, legislation that led to the creation of the National Aeronautics and Space Administration (NASA) on October 1, 1958.

The Benefits of the POES in NPOESS

POES supplies a complete spatial view of global environmental conditions on a regular basis. Accurate weather forecasts depend on high resolution and reliable input to numerical models, which comes predominantly from POES. Instruments aboard Polar-orbiting environmental satellites collect parameters such as wind, temperature, precipitation, and air pressure with height in the earth's atmosphere. These are used to initialize weather prediction models. Without correct "initial conditions," the



When looking at visible images it is sometimes difficult to tell the difference between clouds and snow on the ground (under mostly clear skies). The false color image (right) allows meteorologists to quickly determine the difference between clouds (white), water (black) and snow cover (orange). Bare ground and vegetation is green. This image was taken from the NASA MODIS sensor on board the Terra satellite. NODIS is a precursor to VIIRS that will fly on NPOESS.

forecasts would be severely flawed. Dr. Ron McPherson, Executive Director of the American Meteorological Society and former Director of the National Centers for Environmental Prediction states when referring to POES that "...when these data became available, global weather predictions became practical."

Historically, profiles of the atmosphere were taken only twice daily via instrument packages called radiosondes that are attached to weather balloons and launched in areas in or near population centers. Though data from the sparse global network of radiosonde stations are still useful, particularly in validating remotely-sensed data, radiosondes cannot cost effectively provide the necessary data density to support improved forecasts from numerical weather prediction models. Polar-orbiting satellites allow affordable, consistent collection of millions of observations from all across the globe. Data for model initialization can be collected over the Earth's oceans, poles, deserts, mountains, and everywhere in between. Data collected in remote or difficult to reach locations are particularly important as they may yield the keys to otherwise undetected weather system developments a day or two in advance or help scientists to better understand the forcing of environmental change.

In addition, because Polar-orbiting satellites fly closer to Earth, the images produced from visible and infrared sensors on these spacecraft offer a higher spatial resolution, up to 250 meters, than the higher-orbiting GOES instruments which provide 1 km resolution in the visible at best.

In the past, the separation of NASA for research, DoD for military applications, and NOAA for civil operations resulted in separate satellite platforms being launched to monitor similar environmental parameters. In an effort to eliminate unnecessary redundancy and expense, the operational satellites being developed by the NPOESS program will serve the combined needs of NOAA, DoD, and NASA.

While NPOESS will not address all the needs of the research community it will provide a significant cost savings to the nation in addition to valuable data. NASA will continue to fly research missions and develop advanced technologies for use on future operational missions. Advances in our understanding of the planet as a whole and the predictions of how it may change in the future, will continue to rely heavily on satellite-provided data.

POES in use today also carry a payload to support the Search and Rescue

Atmospheric Sensors

Satellites collect data using instruments known as sensors. Atmospheric sensors generally fall into one of two primary categories: imagers or sounders.

There are three types of imagers: optical, infrared and microwave. Optical imagers usually use a rotating mirror and telescope in combination with a radiometer, to scan the Earth's surface and its atmosphere. They measure radiation at specific bandwidths, or channels, of a spectrum, including color in the appropriate spectral region. At least one channel measures visible radiation, while at least one other measures infrared radiation. Visible images need sunlight, but infrared images can be taken during the day or night. Data are collected and sent back to earth, where they are processed to produce images or products that are useful to the scientist, researcher, military decision maker or other user.

Microwave imagers are of two types: those that transmit ("active") microwave signals to the surface of the Earth and measure the reflected signal or those that receive ("passive") microwave energy from the surface of the Earth. Power reflected by objects the "active" microwave signal encounters is called backscatter. Rough objects such as cities create more backscatter and result in brighter images, while smooth objects such as bodies of water create less backscatter and result in darker images. Microwaves can penetrate clouds and adverse weather conditions. The images they generate can be acquired during the day or night. Naturally-emitted microwave radiation can be measured by "passive" sensors from which images can be produced. NPOESS will employ one "active" microwave instrument, a radar altimeter, and two "passive" microwave instruments, the Conical-scanning Microwave Imager/Sounder (CMIS) and the Advanced Technology Microwave Sounder (ATMS), amongst the first three NPOESS satellites.

Sounders are found on most operational environmental satellites. Because they collect data samples from different levels of the atmosphere, they can be used to produce a three dimensional array of atmospheric measurements of conditions such as temperature, humidity, and pressure. Data collected by sounders are sent back to Earth for assimilation and processing into numerical weather prediction models and meteorological overlays that can be combined with other satellite imagery to monitor climate trends and variability.

An example of a sounder is the TIROS (Television Infrared Observation Satellite) Operational Vertical Sounder (TOVS), which takes profiles of the atmosphere and monitors temperature and humidity variations at different altitudes. Data collected support a broad range of environmental monitoring applications such as weather forecasting and analysis and climate research and prediction. TOVS is a suite of sounding instruments comprised of the High Resolution Infrared Radiation Sounder (HIRS), the Microwave Sounding Unit (MSU) and the Stratospheric Sounding Unit (SSU).

Satellite Aided Tracking System (SARSAT). Boaters, climbers, military personnel, or others in remote areas can push a button on a small transmitting device that sends a signal up to NOAA's POES, which in turn sends a signal alerting authorities where to execute a rescue operation for a person in distress.

Currently NASA's EOS satellites Terra and Aqua are equipped with prototype sensor technology that is similar to what will fly on NPOESS. Now on Terra and Aqua, the Moderate Resolution Imaging Spectroradiometer (MODIS) is a precursor to the Visible Infrared Imager Radiometer Suite (VIIRS) on NPOESS. The MODIS instrument collects approximately 38 environmental variables related to air, land and water surfaces, and temperatures. It also images ocean color to examine ocean productivity and potential algal blooms.

Flying currently on Aqua is the Atmospheric Infrared Sounder (AIRS). Managed by officials at Jet Propulsion Laboratory, AIRS, as well as the Advanced Microwave Sounding Unit (AMSU) and the Humidity Sensor for Brazil (HSB) collect temperature and humidity profiles of the atmosphere. AIRS technology is similar to the Cross-track Infrared Sounder (CrIS) that will be flown on NPOESS. Data from AIRS are already flowing into Numerical Weather Prediction Models at the National Centers for Environmental Prediction (NCEP) through efforts funded by the NPOESS program over the last 3-4 years. This will be discussed in future articles.

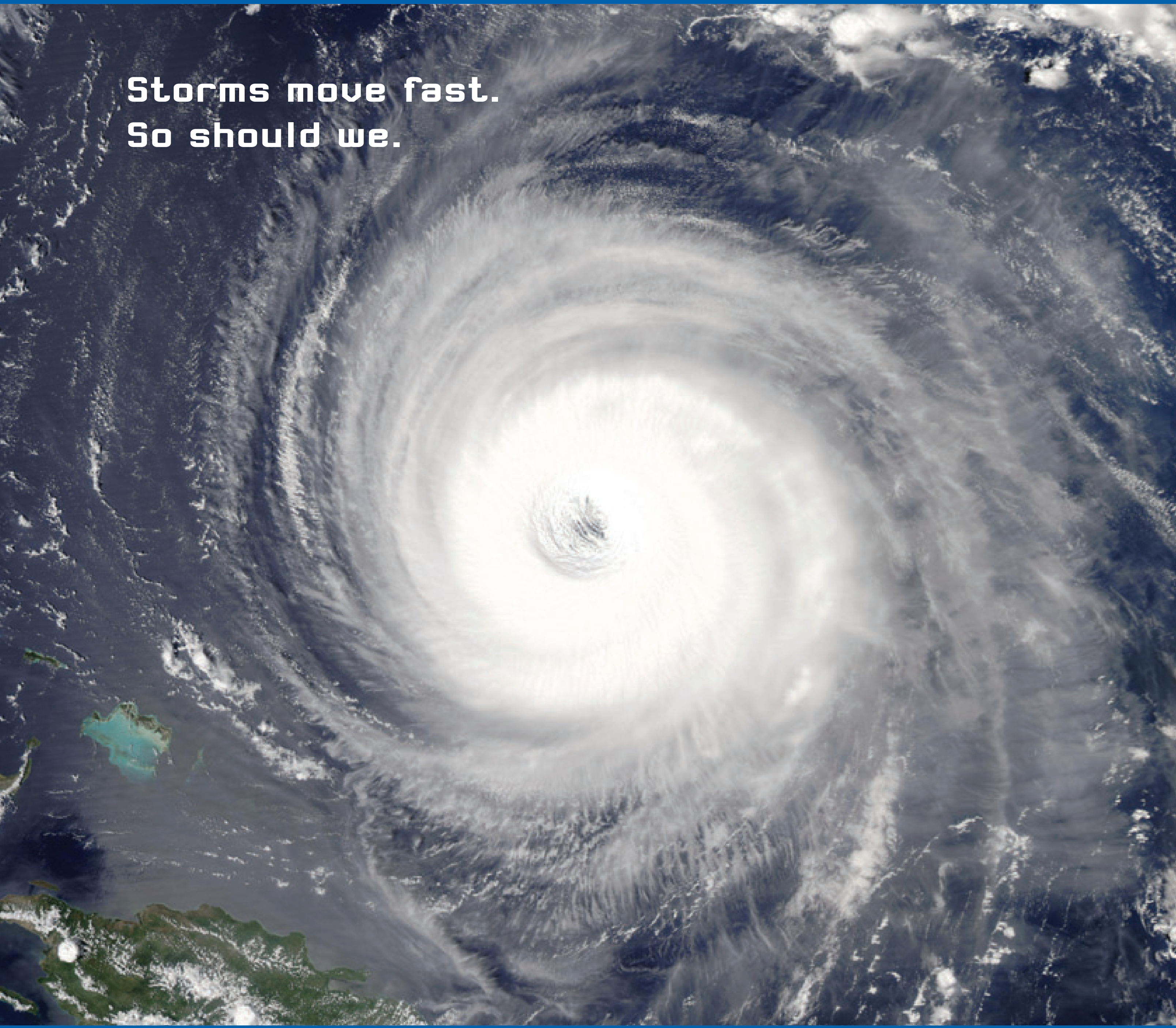
The advanced, cutting-edge sensors that will be launched on NPOESS satellites will increase the accuracy of weather forecasting, scientific research, and environmental monitoring. Network technology implemented to deliver NPOESS data will increase the timeliness of data delivery to users. Data will also contribute significantly to the support of general aviation, agriculture, maritime activities, U.S. military objectives, and space weather applications.

The greatest beneficiaries of NPOESS will ultimately be to the nation's citizens who will benefit from improved weather forecasting, safer and more informed military and transportation operations, more efficient agriculture, improved search and rescue, and a better understanding of the planet, including both the natural and anthropogenic influences. NPOESS is a significant technical advance toward greater efficiency, coordination, and productivity for societal value in the government.

Future articles will take a closer look at the NPOESS program. Next month's article will outline the specifics of the NPOESS program including its origin, its expected products, and the path sensors have taken from research to actual operation.

About the Author

Dave Jones is Founder, President and CEO of StormCenter Communications, Inc. He is also President of the ESIP Federation *(esipfed.org)* and Chairman of the Board for the Foundation for Earth Science.



The fury of a fast-moving hurricane is bad news. That's why we need the National Polar-orbiting Operational Environmental Satellite System (NPOESS). A remarkable technological leap, NPOESS will provide clearer images and better environmental data, faster. It will allow more timely and accurate forecasts that can save lives, resources, property. The continued aggressive pursuit of NPOESS is critical because the technology is so widely beneficial. And the NPOESS team is moving quickly to make it happen.

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